Таблица 1. Результаты исследований

№ пп.	Об/мин	Давл.	Разреж.	Ток	Нап-ряж.	Мощ-ность	Наг-рузка	Коор-дината	Тем-пер	Time	Date
0	100	255	255	2,55	60	153	0	-1	0	20:02:41	19.03.2011
1	115,5	255	255	2,55	60	153	0	-0,91	0	20:02:59	19.03.2011
2	132,03	255	255	2,55	60	153	0	-0,65	0	20:03:13	19.03.2011
3	162	255	255	2,55	60	153	0	-0,45	0	20:03:23	19.03.2011
4	187,83	255	255	2,55	60	153	0	-0,23	0	20:03:31	19.03.2011
5	211,6	255	255	2,55	60	153	0	0,01	0	20:03:39	19.03.2011
6	132,03	255	255	2,55	60	153	0	-0,65	0	20:03:43	19.03.2011
7	162	255	255	2,55	60	153	0	-0,45	0	20:03:48	19.03.2011
8	187,83	255	255	2,55	60	153	0	-0,23	0	20:03:52	19.03.2011
9	211,6	255	255	2,55	60	153	0	0,01	0	20:03:59	19.03.2011
10	132,03	255	255	2,55	60	153	0	-0,65	0	20:03:63	19.03.2011
11	162	255	255	2,55	60	153	0	-0,45	0	20:04:28	19.03.2011
12	187,83	255	255	2,55	60	153	0	-0,23	0	20:04:32	19.03.2011
13	211,6	255	255	2,55	60	153	0	0,01	0	20:04:49	19.03.2011

Графический интерфейс (рис.6) программы дает возможность визуально наблюдать в реальном времени необходимые графические зависимости с сохранением изображений (рис.7) в памяти ПК.

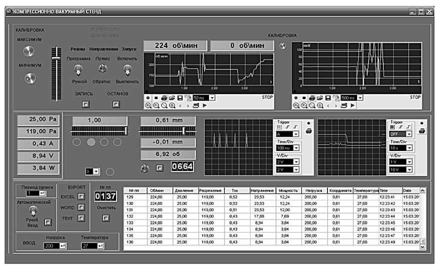

Рис. 6. Внешний вид графического интерфейса программного обеспечения

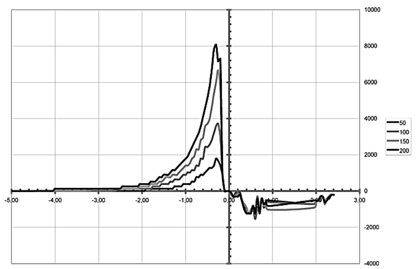

Рис. 7. Результаты экспорта и первичной обработки измеренных параметров

Графический интерфейс в совокупности с программными модулями математической обработки экспериментальных данных позволило создать наглядную, удобную и относительно простую автоматизированную систему регистрации параметров и управления режимами трения скольжения.

Выводы

Использование базовых аппаратных и программных модулей систем с разработанными программными модулями математической обработки экспериментальных данных и формирования алгоритма управления позволило за короткое время и с минимальными финансовыми и аппаратными затратами спроектировать и создать эффективную автоматизированную измерительно-испытательную систему определения компрессионно-вакуумных составляющих процессов трения скольжения.

Разработанная и внедренная система значительно повысила производительность экспериментальных исследований трибореологических свойств смазочных материалов, исключая влияние человеческого фактора (субъективное принятие решений оператором).

Графический интерфейс программного обеспечения позволяет формировать алгоритмы управления, визуальное наблюдение в реальном времени необходимых графических зависимостей.

Управляющий позиционно-сканирующий механизм обеспечивает равномерность износа деталей при трении, что повышает достоверность результатов исследований.

EXPERIMENTAL COMPARISON OF DIFFERENTIAL-PHASE METHOD AND METHOD OF DYNAMIC FOCUSING IN DEFINING OF ROUGHNESS PARAMETERS OF SURFACES

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Almost all modern machines and mechanisms consist of friction nodes, which realize contact interaction of details with working surfaces in relative motion between each other. From tribology of boundary greasing it is known that there is great influence of surface roughness on tribological properties of rolling or sliding tribosystems. Due to this fact during production of details different quantitative methods for determination of roughness parameters are widely used (such as profilograph-profilometer CALIBR-201, “TEYLOR HOBSON”, “SURTRONIC-10”. Contac methods allow describing micro-geometrical surface structure only according to single profiles and they can’t give information about volumetric surface condition, which is very important during friction in dependence of direction of exploitation and influence on wear resistance of tribosystem.

Nowadays contactless optical methods and equipment such as laser contactless differential-phase method and method of dynamic focusing (in DFLSPP of Ukrainian production and microscope “*μscan*” of German production correspondently) are used instead of contact, less informative and destroying methods. This new equipment and methods can give essentially new, qualitative and quantitative information about volumetric 3D micro- and nanometric geometrical surface condition. In this work are presented results of experimental investigations of rough surfaces done with a help of DFLSPP and *µscan*.

Today for controlling of working surface roughness of details with friction nodes contact methods still are used. In contact method needle with a circular diameter 2…4 mkm slides on a surface of sample in a linear direction. This method can be used for determination of wear traces after tribotechnical tests.

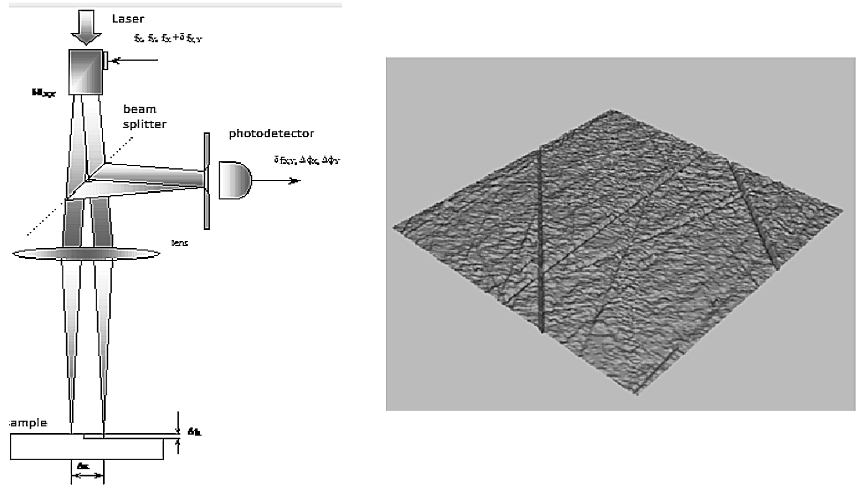
After experiments done on friction machine with a constant linear contact radial deviations are more then 1 micrometer, axial- 0,1 micrometer. That is why we can say that one of the main factors, which influence on results of tribological experiments of lubricating materials, is external structure of working surface of samples after friction.

But usage of contact method can provide us with necessary information about structure of surface, and can't give full information about surface, such as roughness in a direction of sliding. This information have influence on character and value of wear.

Moreover, equipment which is based on contact method can scan surface only in one linear direction. In such conditions it is very hard to make volumetric estimation of surface structure. Indentor (needle) which is used for estimation of friction surface have circular radius (approximately 2 micrometers). That is connected with technological features and design of equipment and sensitive elements, which realize this contact method. Because of that we have such consequences like that hardware can't fix geometrical character of surface if it has roughness less than diameter of needle. That is why only contactless optical method can provide us with full information about 3D volumetric surface structure.

DFLSPP of Ukrainian production was created for reception of true information about surface structure and reception of differential-phase picture. Principle of action of this equipment is based on acoustic-optical scanning of object with the help of laser beam, which is divided in two orthogonal directions in crystal of parateluryte. During scanning this beams are reflected from surface creating 3D differential-phase picture (pic. 1).

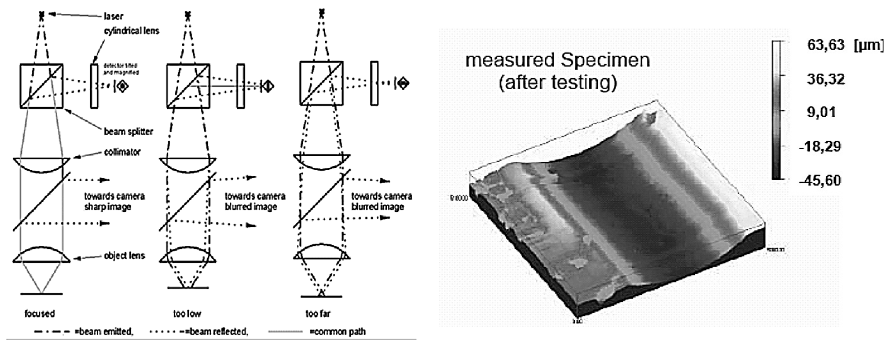
For investigation of phase changing from reflected light waves in surrounding is used differential-phase method. This method allows creating optical scheme tolerant to vibrations.



Pic.1. Laser contactless differential-phase method

Method is based on reception information about local difference of phases of two beams (basic and alarm), from which we can receive information about local curvature of wave front surface by scanning and integrating of defined values.

METHOD OF DYNAMIC FOCUSING Microscope µscan of German production by firm NanoFocus [4] was created for the same purposes as DFLSPP. But principle of action of this microscope is not the same. It has focusing sensor and movable lens, which provide auto-focusing by moving of lens along measurement scale (pic.2).



Pic.2. Method of dynamic focusing method

Investigated object moves under laser beam with the set speed and information about moving of movable lens in dependence of height of surface relief goes to computer. The more focused points we will have the better picture will be received. The maximal investigated area is 10x10 см^2.

EXPERIMENTAL DEFINITION OF POSSIBILIES OF DFLSPP AND "MICROSCAN"

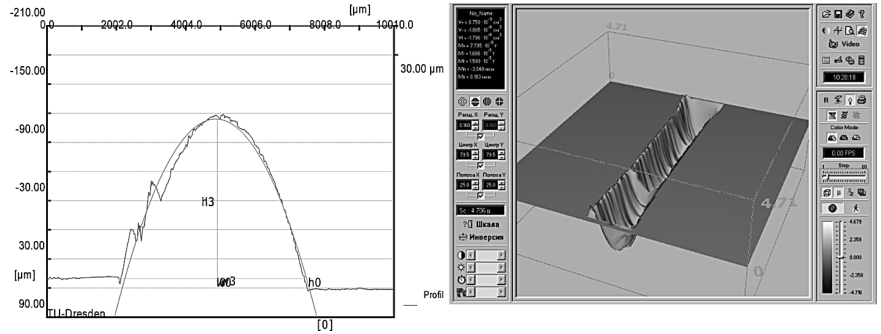
Important peculiarity of DFLSPP and microscope µscan is possibility to define and calculate volumetric structure of rough surfaces. Software of that equipment allows defining main roughness parameters of investigated surfaces of samples. Both microscopes have different methods of calculation, that is why they also have different technical characteristics. Thus on DFLSPP can be calculated standardized roughness parameters of samples in a range 0,005…0,320 micrometers and on µscan in a range 0,025…1250 micrometers (Table1). But on microscope µscan this calculated roughness parameters are also compared with international standards ISO, which can be chosen for different materials.

Also it has to be mentioned, that very important parameter during investigations of the sample is its reflection ability. For DFLSPP can be also investigated objects with reflection ability less then 50%, bun in this case lenses on profilograph-profilometer should be changed.

Table 1. Technical characteristic of microscopes

№	Technical parameters	Microscope			
		DFLSPP		µscan	
		Type of objective lens			
		PLAN, F=6,3, A=0,65	PLAN, F=16, A=0,3	autofocus	
				AF2	AF5
1	Max.scanning area, mm	2,5×2,5 0,8×0,8	5×5 3×3	100×100	
2	X, Y- resolution, mcm	0,8	0,6	1	1
3	Curvature of surface, degree/mcm	20	8	26	19
4	Reflection coefficient of the surface, %	≥50		0…100	
5	Height of measured step of relief, mcm	≤0,32		≤1500	
6	Resolution for relief, nm	≤10		≥25	
7	Type of scanning	Acousto-optical		mechanical	

Microscopes Nanofokus and LDFSPP are used for definition size of deterioration of modeling bearings of sliding after friction in laboratory conditions. In the pic. 3 are presented profile of trek after friction, received on a microscope Nanofokus in the laboratories of the Tribotechnics of ILK TU Dresden and 3D image of a trek after friction received on LDFSPP in laboratories Nanotribotehnology NAU Kiev.



a *b*

Pic. 3. Profile of trek after friction by NANOFOCUS (*a*) and 3D view of trek after friction by LDFSPP (*b*)

CONCLUSION

Choosing equipment for estimation roughness parameters consumer need technical and economical comparison of this equipment to decide which one is better for purchase. Comparison of technical abilities had shown that differential-phase method has next advantages:

- Is insensitive to vibrations;
- Microscope can provide measurements of surface parameters to 1 nm on height of relief;
- Investigated object is immovable;
- Object with any size can be investigated.
- But in this method we don't have autofocus and have not so big working range (height of relief can be measured in range 1…320 nm). Disadvantages of differential-phase method are realized in method of autofocus. And we can name its advantages:
- Wide measurement range;
- Autofocus;
- Sample with surface with any reflection coefficient can be investigated.
- In method of dynamic focusing we have next disadvantages:
- Sensitivity on height of relief is smaller then in DFLSPP;
- Mechanical scanning, which lead to vibrations and decrease sensitivity of microscope.

Comparison of all this advantages and disadvantages, general technical characteristics and price of this equipment show that such investigations are very important for consumers for making of an optimal choice of microscope for work in definite conditions.